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THE OPTICAL LANTERN

AS AN

AID IN TEACHING.

BY

C. H. BOTHAMLEY.

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PREFACE.

THE matter of this book originally appeared in the form of articles in the *Photographic Quarterly*, and is now republished, with some slight additions, in the hope that it may help the introduction of the lantern as an every-day appliance in elementary and other schools. The author's experience as a teacher enables him to speak in the highest terms of the value of the lantern as an educational instrument, and it was a desire to show how easily and cheaply the advantages arising from its use may be secured that prompted the writing of the articles.

The second part of the book contains nothing that is new, but the author has been careful to make no statements that are not the result of actual experience.

C. H. B.

THE OPTICAL LANTERN AS AN AID IN TEACHING.

PART I.

THE EMPLOYMENT OF THE LANTERN IN CLASS TEACHING.

IT is not so very long ago that the greater part of the work done in ordinary schools consisted of committing to memory certain specified portions of text-books, which were reproduced piecemeal or in their entirety in response to questions from the master, who considered that he had done his duty towards his pupils when he had "heard them their lessons" and set fresh tasks for the following day. It is teaching of this kind, carried on by the lineal descendants of the famous Dr. Blimber, that is responsible for the startling information that "Gibraltar is an island built on a rock"; "Cape Hatteras is a vast body of water"; "Mason and Dixon's line is the Equater (*sic*)"; "the stomach is a small pear-shaped bone situated in the body"; "the optic nerve is the principal nerve used in digestion"; "the molars are the teeth that grow outside

the head"; and the like.* Some of us have heard, too, of examinees in Biology who had never looked through a microscope, and of so-called teachers of Chemistry whose only apparatus was a blackboard and a piece of chalk. Teaching of this kind—if indeed it can be called teaching at all—develops only one faculty, the memory; and tends at the same time to develop, from the very repulsiveness of the method, an ineradicable dislike to the acquirement of knowledge of any kind and in any form. Education in the proper sense of the word it certainly is not. Happily, however, this method, with many other educational absurdities, is surely, if slowly, passing away. The faculties of observation and reasoning are no longer neglected, and it is becoming generally recognised that, as a gateway of knowledge, the eye is not less important than the ear. An acquaintance at first-hand with the objects or phenomena to be studied is the thing to be aimed at, and not the mere memorising of what somebody has said more or less accurately about them. Even where, as in many cases, direct acquaintance is not possible, a careful drawing, or, better still, a photograph, is worth an hour's mere oral explanation; and a later and wiser race of teachers is being developed, anxious to reach the minds of their pupils by the most direct path, and on the alert to acquire means of illustration which will enable them to clothe the dry bones of their facts in attractive garments.

* "English as She is taught" (Field, Tuer, & Co.).

It is, I think, beyond question that teachers as a body have not yet recognised how valuable an assistant they have ready to their hands in the optical lantern, probably because they are unaware of the important modifications and improvements that have been made in the instrument in the last few years. Popular lecturers, and the higher class of teachers of science, have of course frequently employed the lantern for purposes of illustration, but its use in connection with schools has been confined to purposes of entertainment; and the idea that it might be used, and ought to be used, constantly as an aid in the daily work of the school, will probably be new to most schoolmasters. In cases where such an idea has been entertained, it has generally been given up as impracticable; mainly, I imagine, because it was supposed that the apparatus required was very costly, and that its use involved a very large amount of trouble. One of the chief objects of this little book is to show that such objections have no foundation in fact.

It is the general belief that a lantern can only be used effectively in a darkened room; and it is objected, with reason, that the darkening of the room whenever a few slides have to be shown is very troublesome, interferes with the taking of notes by the pupils, and last, but not least, affords an opportunity for mischief and disorder of which the less earnest portion of the class is not slow to take advantage. It is in fact indispensable, if the lantern is to be used at all generally for class-work, that it should

be used in a room so well lighted that students can take notes comfortably, and that no additional difficulty in maintaining discipline is placed in the way of the teacher. It is also essential that the teacher should be able to perform all the necessary manipulations without the aid of an assistant, and without interfering with his proper work of teaching. Many considerations that are of great importance when the lantern is used purely for exhibiting pictures as such, need not be taken into account at all. Great brilliancy of illumination is unnecessary; it is sufficient if the pictures or diagrams are easily and distinctly visible. Only a small screen, however, is required, and the increased brilliancy of the smaller disc compensates for a considerable amount of diffused light, and slides can be shown effectively in a room so well lighted by daylight or gaslight that ordinary print can be read with comfort. All that is necessary is to place the screen so that no light falls directly on it from the windows or gas-burners, and to avoid excessive general illumination of the room by drawing down the blinds or regulating the number of gas-burners. Many lantern manipulators are in the habit of exhibiting at night-time in a room with sufficient diffused illumination to enable the audience to move about and to see one another; but, so far as I am aware, the first to demonstrate the possibility of using a lantern *successfully* in a room illuminated by daylight, was Mr. L. C. Miall, Professor of Biology in the Yorkshire College, and he certainly was the first to put

the plan into actual and continuous operation for the purpose of illustrating courses of lectures.

There is probably no other educational institution in which the optical lantern is used to such a large extent for ordinary class-work as in the Yorkshire College, Leeds, one of the colleges of the Victoria University, the initiation and growth of the system being due to Professor Miall. Almost every department has its lantern, and such widely different subjects as Biology and Engineering, Ancient History and Textile Industries, are illustrated by the same means. An account of what has been done and is being done in this college will probably be more convincing than a whole volume of speculative suggestions as to what might be done.

How far diagrams and photographs shown by means of the lantern can or ought to replace large diagrams hung upon the walls is a question of considerable importance. Diagrams have undoubtedly certain advantages over lantern-slides. They remain in view of the student during the whole of the lecture or lesson, and can be left on the wall for some time afterwards. Opportunity is thus given for careful consideration of the facts tabulated, and, if necessary, for making a sketch of the object represented. If the same matter is exhibited in the form of a lantern-slide it cannot remain on the screen for long, and the time given for its consideration may not be sufficient for the sluggish comprehension of a dull student. Chiefly for this reason it is held by some of the best teachers of

science, and especially of technology, that for their purpose diagrams are indispensable, and cannot be replaced by slides. The weight of this objection will, however, vary with different subjects; there are many instances, too, in which prolonged examination of a diagram is not at all necessary, and others in which a photograph shown in the form of a lantern-slide is of far greater value than any number of diagrams. Cost of production, facility for storage and exhibition, are also very important matters. Diagrams, if at all elaborate, are very costly, and the expense of any considerable number would be so great as to be prohibitive except in the case of the wealthiest institutions. Moreover, they are bulky and occupy much storage room, are very liable to be damaged, and if at all large are very troublesome to put up for exhibition.

Lantern-slides, on the other hand, can be prepared very cheaply, occupy very little space, and are easily exhibited. Their use, too, enables a much larger number of illustrations to be shown, not only because of the smaller expense, but also on account of the space required for their exhibition. A hundred or a thousand lantern-slides can be projected successively on one small screen, but it would require the walls of a very large room to support fifty diagrams. With respect to expense, there are in my own knowledge several cases in which the cost of slides to illustrate particular lectures was much less than a quarter of the cost of an equivalent set of diagrams. In not a few cases, moreover, it is practically impossible to

reproduce a subject in the form of a diagram because of its complexity, but the preparation of a lantern-slide presents no great difficulty.

Experiments, wherever practicable, should be made on a sufficiently large scale to be visible to a class of moderate size, but in cases where only a small piece of apparatus can be used, and where the motion or whatever else has to be observed is very small, the lantern is the only means of making the result visible to a large class. We are, however, at present almost exclusively concerned with the illustration of various subjects by means of pictures or diagrams in the form of slides.

The arrangements adopted at Leeds vary somewhat according to the form and mode of lighting of the particular lecture-room; but the general principle is the same in all cases, and they may be taken as typical of arrangements which would answer quite well under all ordinary circumstances. The most novel and important points are that *the slides are exhibited in a well-lighted room, and all the necessary manipulations are done by the lecturer or teacher without any difficulty.*

The lecture table is usually 3 ft. high, and the lantern, supported as a rule on a small sloping stand, is placed on the table in such a position that the taps of the burner and the carrier for the slides are within easy reach. The slides that are to be shown are placed in order in a small pile near the lantern, or, if any one slide is to be shown several times during the same lecture, they are

arranged on a sheet of white paper so that any particular slide is easily picked out.

The screen is placed against the wall behind the lecture table, and therefore facing the class, the distance between the screen and the lantern being from 6 ft. to 8 ft. The rooms are lighted only from one side, and in some cases the

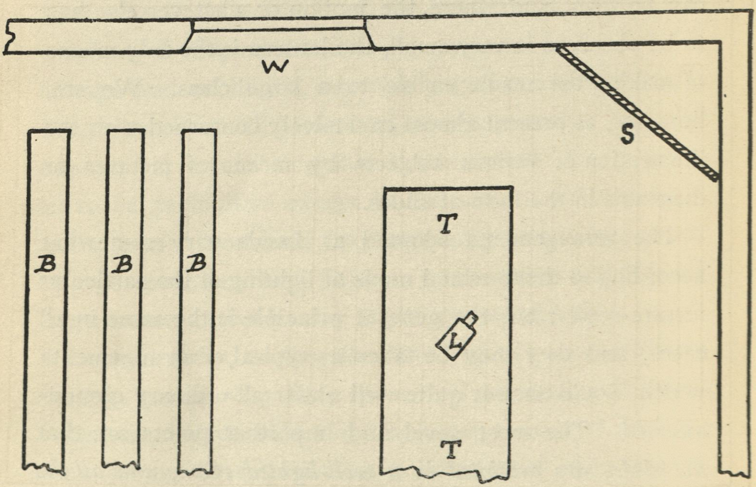

FIG. 1
B. Benches. T. T. Table. L. Lantern. S. Screen. W. Window.

screen is placed at an angle in the corner of the room near the windows (Fig. 1). It is necessary to have the centre of the screen somewhat higher than the lecture-table, and hence it is not only placed cornerwise, but is also inclined at a slight angle with the wall. In other cases the screen is placed behind the middle of the table, and the difficulty of preventing the light from the windows from falling on

it is somewhat greater. The screen must be at some height above the lecture table, in order that the lantern may not obstruct the view, and by drawing blind No. 1 (Fig. 2) down completely, and Nos. 2 and 3 partly down, the screen is in shadow whilst sufficient light is thrown

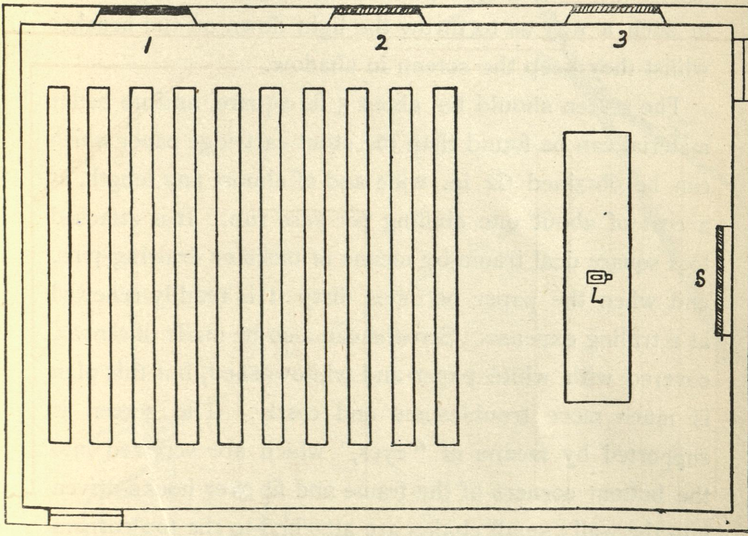

FIG. 2.
L. Lantern. S. Screen.

upon the benches. The raising of the screen to some height above the table is also necessary in all cases where the seats are on a level, but when they are arranged on a slope, and the screen is in the corner, it is sufficient if the bottom of the screen is level with, or even below, the top of the table. If the room is used at night, the screen

must be protected from the direct light from the burners. When the room is high and the lights are near the top this can be done by having a strip of wood or other opaque substance projecting from the top of the screen at right angles with its face (D, Fig. 3), but if the burners are low a screen of tin plate must be placed behind them in such a way as to throw the light down on the benches whilst they keep the screen in shadow.

The screen should be about 5 ft. square, and no better material can be found than the stout cartridge paper which can be obtained 62 in. wide and of almost any length, at a cost of about one shilling per yard run. It is attached to a square deal frame by means of tacks or drawing-pins, and when the paper becomes dirty it is readily renewed at a trifling expense. Screens can also be made of canvas, covered with white paper and whitewashed, but this plan is much more troublesome and costly. The screen is supported by means of "eyes," which are screwed into the bottom corners of the frame and fit over hooks driven into the wall; small chains are attached to the top corners of the frame, and their other ends pass over other hooks in the wall, the length of the chains determining the inclination of the screen. When the difference between the lighting of the room in the daytime and at night makes it necessary to alter the slope of the screen, two frames may be used, hinged together at the bottom. The front frame carries the screen, whilst the back frame is attached to the wall; and slotted iron struts, which can be clamped

by means of screws, are attached to each side of the screen so that the latter can be fixed at any angle (Fig. 3).

The body of the lantern should be small, and the

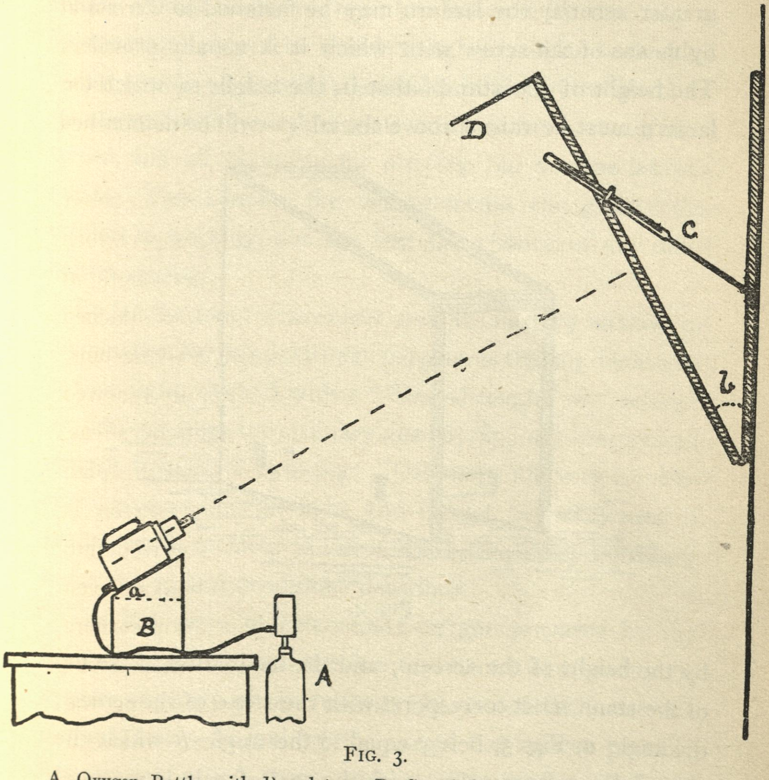

FIG. 3.
A. Oxygen Bottle with Regulator. B. Stand for Lantern. C. Strut for adjusting Screen. D. Protection against Top Light.

chimney as low as possible, in order that it may not obstruct the view of the screen. It should be placed on a small sloping wooden stand (Fig. 4), the top of which

is a board a little greater in length and breadth than the base of the lantern, with a narrow fillet of wood running all round it to prevent the lantern from slipping. For greater security the lantern may be fastened to the stand by means of the screw with which it is usually provided. The height of the stand—that is, the height to which the lantern must be raised above the table—will be determined

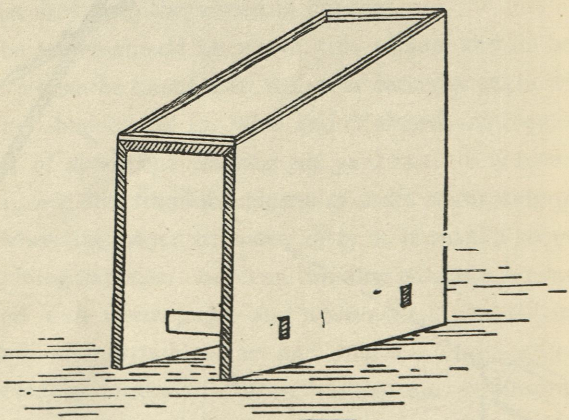

FIG. 4.

by the height of the screen ; and the inclination of the top of the stand must correspond with the slope of the screen ; the angle *a*, Fig. 3, being equal to the angle *b* which the side of the screen makes with the wall, for it is essential that the front lens should point directly to the centre of the screen and that the axis of the lantern lenses should be perpendicular to the face of the screen, otherwise the image will be distorted and badly defined. If the slope of

the screen has to be changed it will be necessary to make a corresponding change in the inclination of the lantern; and this is provided for by having the top of the stand hinged so that it can be raised or lowered by inserting a wedge which should be broad enough to rest on both sides of the stand. It is very desirable, however, to avoid as far as possible all complications in the lantern, stand, and screen, and all necessity for altering the various adjustments. The simpler the arrangements the greater the comfort in working, and the less the chance of any difficulties arising.

By far the most convenient and satisfactory method of illumination for this particular purpose is the oxy-hydrogen or lime light, worked with a "blow-through" or "safety" jet, coal-gas from the ordinary gas supply, and compressed oxygen from steel cylinders. Oil lamps are very troublesome, give an inferior light, and cannot be safely used if the lantern is inclined as much as is frequently necessary under the special conditions described.

The low price of compressed oxygen prepared by the Brin's Oxygen Co., and the fact that it can now readily be sent to any part of the country, is one of the most important factors in making the use of the lantern possible for general school-work. All trouble in the shape of preparation is reduced to a minimum.

The exhibition of slides being provided for, it is necessary to determine what subjects can be most profitably illustrated in this way. Projection of experiments in

Natural Philosophy and Chemistry, may be left out of consideration as already quite familiar. In the Yorkshire College, the lectures on Engineering, Dyeing, and the Textile Industries, are profusely illustrated by photographs and drawings (often reproduced by photography) of machines and parts thereof, of plants yielding colouring matters, etc., micro-photographs of fibres, etc., and designs for textile fabrics. The number of illustrations possible in this way is far greater than if diagrams were used. The lectures on Biology are illustrated by micro-photographs of drawings and of the actual objects. So convenient and successful has the plan proved that the microscope is rarely used for lecture illustrations, but is relegated to its proper place in the laboratory. A great saving of time is thus effected, for a lantern-slide of a micro-photograph can be seen by and explained to the whole class at once, whereas an object under a microscope must be shown to each student separately. Passing now to subjects more closely related to ordinary school subjects, the Professor of Classics, Principal Bodington, tells me that when teaching Classical texts, he has found photographic lantern-slides invaluable for the reproduction and exhibition of maps and plans such as those which illustrate Napoleon III.'s account of the campaigns of Cæsar, whilst photographs of the famous localities and buildings of antiquity have been most useful in impressing upon students the reality of the subjects that they were studying. In the department of Art and Design, photo-

graphs of the great masterpieces and other instructive examples are exhibited with much advantage to the students. Courses of lectures on Geography have been given to teachers engaged in the elementary schools of the district, and the use of the lantern enabled the lecturer to give a large number of illustrations that could not possibly have been given without its help.

Here we have highly successful experience in the use of the lantern to illustrate three subjects that are commonly taught in schools, and there is no reason why other subjects of a school curriculum should not be treated in the same way. Languages and Mathematics are, of course, beyond the scope of pictorial illustration, and the diagrams in the latter subject are much more instructive if built up on the blackboard before the students. Geography, Physiography, and Natural History lend themselves most readily to treatment of this kind; but in teaching History (modern as well as ancient), maps and plans, which can be so easily reproduced by photography, together with photographs of the most famous places and persons—the latter from paintings or engravings—would create interest in a subject which, as it is now taught, is not uncommonly regarded by pupils with great aversion.

The production of lantern-slides is most easily and rapidly done by photography. Original objects, drawings, large photographs, illustrations in text-books, can all be reproduced in the same way. At the Yorkshire College the number of slides required by the various departments

is so large that the whole time of a special photographic assistant is occupied with their production, although the work is much facilitated by the ingenious copying camera devised by Professors Barr and Stroud.* Very good slides, illustrating almost all subjects, can now be purchased very cheaply, and there is little doubt that if a general demand arose for sets of slides for school purposes, the leading professional producers of slides would meet the demand at still lower prices. There are several non-photographic methods of making slides which will give very good results in the hands of any one who can use a pencil. Thin and finely-ground glass of the proper size ($3\frac{1}{4}$ in. square) can readily be drawn upon with a finely pointed but somewhat soft pencil, and when the drawing is finished a solution of Canada balsam in benzene is poured on the glass and allowed to harden. This makes the glass practically transparent, and a cover-glass is afterwards put on in the ordinary way. A method that I have frequently used with success is to immerse the carefully cleaned glass plates (not ground) in a solution of gelatine containing 2 to 3 grains per fluid ounce, and allow them to dry out of contact with dust. The surface of the glass is now covered with an extremely thin film of gelatine, and can be drawn or written upon quite easily. Liquid Chinese ink gives the best results, and

* *Eng. Pat.*, 1889. This copying camera can be obtained complete from W. Middlemiss, Bradford, Yorks, and costs, with lens and lamps, £10.

a pen with a fine rounded or turned-up point should be used. Either plan is available for writing out tables of figures and making simple diagrams and sketches. If necessary, the glass may be laid over a drawing, which can then be copied by tracing it; but for all elaborate subjects copying by photography will be found cheaper, quicker, and much more satisfactory.

Slides can be stored in grooved boxes, or in boxes without any grooves but with a limited number of divisions. When the number is large it is better to have a small wall case, a little more than $3\frac{1}{4}$ inches from back to front, with vertical divisions a little more than $3\frac{1}{4}$ inches apart. Horizontal shelves are inserted at such a distance that each compartment easily holds ten, twelve, or twenty slides, leaving room at the top for the insertion of the thumb or finger. The front edge of the shelf in each compartment is hollowed in order to facilitate the handling of the slides.

Cost is always an important consideration in matters of this kind, but no very formidable expenditure need be incurred. A useful lantern can be obtained for thirty-five shillings; and a really serviceable one, capable of being used on a large screen, for fifty-five shillings, including the jet. A Beard's Automatic Regulator costs thirty shillings. The cost of the screen and the stand for the lantern will vary according to circumstances, but should be under £1 for the two. We may therefore put the cost of a serviceable outfit at about five guineas, but to this

of course must be added the cost of slides. Current expenses will be simply for limes and oxygen; no charge is made for the loan of the cylinders containing the oxygen, provided that they are not kept beyond a certain time.

It will be seen that the constant use of the lantern for ordinary class-work is not only practicable, but the provision of the necessary apparatus involves no extravagant outlay. Of its great utility there can be no question. It is a trite saying that things that we see are better remembered than things that we merely hear or read of, and this is even truer of children than of adults. Every one knows, too, how enthusiastic children become over anything in the shape of a picture and how eagerly they will listen to an explanation of its meaning; and the use of the lantern would at any rate excite in the pupils, and possibly in the teacher also, an interest in their lesson that is not seldom conspicuous by its absence. The example and practice of the Yorkshire College has been followed on a smaller scale, but with very gratifying results, in several High Schools in the district; and it is to be hoped that the day is not far distant when an optical lantern, with its sets of slides, will form part of the equipment of every school, and its use be as common as the use of the blackboard.

PART II.

MANIPULATION OF THE LANTERN.

IT is now necessary to describe the forms of lantern most useful for general school work and for demonstrations in technical subjects; to summarise very briefly such principles of construction as must be understood if the instrument is to be used properly; and to explain those points in manipulation which must be attended to in order to secure good results. No attempt will be made, of course, to write a complete treatise on the subject (that, indeed, would require a large volume), and the chapter is written mainly with a view to help schoolmasters and teachers of science who have had no experience in lantern manipulation, but who recognise the great utility of this instrument as a means of illustration, and the great part that it is undoubtedly destined to play in education.

The essential parts of the optical lantern are the light, or, as it may conveniently be called (adopting Mr. Lewis Wright's nomenclature), the *radiant*, the *condenser*, which collects and concentrates the light, and the *objective*, which forms the image. The rest of the instrument consists simply of the casing and supports that enclose these

essential parts and keep them in their proper relative positions.

The Objective, if of the short focal distance that alone will be suitable if the lantern is to be worked by the teacher or lecturer himself, must be a doublet or rectilinear lens. Those supplied with the cheaper lanterns are usually photographic lenses of the type commonly employed for portraiture, and, as a rule, work very well. Other lenses of similar but not quite the same construction are made specially for lantern purposes, and are better when pictures or complex objects have to be shown as perfectly as possible, but are not really necessary for ordinary class work. A good objective must not only give uniform illumination and good definition all over the disc, but must also have a field as flat as possible; that is to say, the image at the edge of the disc and the image at the centre of the disc must both be sufficiently well defined with the lens in the same position. If this requirement is not satisfied, but the image at the edge is blurred whilst that in the centre is sharply defined, and *vice versâ*, the field of the lens is too round, and another lens should be obtained. Further, the lens must be rectilinear, or at any rate must give no perceptible curvature to lines that should be straight, and no perceptible convergence to lines that should be parallel. Both these qualities can be estimated at the same time by putting into the lantern a slide consisting merely of straight lines running horizontally and vertically, great

care being taken that the lantern itself is properly adjusted with respect to the screen. An ordinary slide is of little use for the purpose.

The focal length of the objective should be from 4 to 6 inches if the lantern is to be worked by the teacher from his lecture table, but must be very much longer if it is worked by an assistant from the back of the room, and in this latter case a single lens may be used instead of a doublet. The exact focal length necessary is in every case determined by the size of the disc required and the distance at which the lantern can conveniently be placed from the screen.

The following table gives data sufficient for ordinary class work; the upper horizontal column gives the focal length of the lens *in inches*. The first vertical column gives the diameter of the disc on the screen *in feet*, and the other vertical columns give the distance in feet and inches at which the lens of the lantern must be placed from the screen.

DIAMETER OF DISC.	EQUIVALENT FOCAL LENGTH OF LENS.			
	4	4½	5	6
3 feet.	4 4	4 10	5 5	6 6
4 „	5 8	6 4	7 1	8 6
4½ „	6 4	7 1	7 11	9 6
5 „	7 0	7 10	8 9	10 6
6 „	8 4	9 4	10 5	12 6

For example, if the focal length of the lens is 6 inches, and a disc is required 4 feet in diameter, the lens

of the lantern should be 8 feet 6 inches from the screen. The distances in the table are supposed to be measured from the optical centre of the lens, which may, with sufficient accuracy, be assumed to be halfway between the two lenses composing the ordinary doublet. For all ordinary purposes, the distance may be measured from the front lens.

The lenses are usually fitted into brass mounts provided with a rack and pinion for fine focussing, and the mounts screw into a draw tube by means of which the coarse focussing is effected. They should be cleaned from time to time by dusting with a camel's hair brush, and rubbing with a soft wash-leather perfectly free from grit. Before being used they should be left for some time in the room in which they are to be used, in order to prevent condensation of moisture on their surface. This can only happen when the lenses are colder than the air in the room.

THE CONDENSER usually consists of two plano-convex lenses mounted in brass cells with their convex surfaces inwards and nearly touching one another. Their diameter is usually 4 or $4\frac{1}{4}$ inches, and this is the best for showing slides, but if apparatus is to be projected it is an advantage to have condensers 5 inches in diameter. The function of the condenser is to collect the diverging beam of light proceeding from the radiant, and convert it into a converging beam which passes through the

object into the objective, the latter forming the image (Fig. 5). If there were no condenser, only a very small fraction of the light would be utilised in forming the image on the screen. The best relative positions of the radiant, the condenser, the object, and the objective depend on the focal length of the condenser and the objective; they must be so arranged that the converging cone of

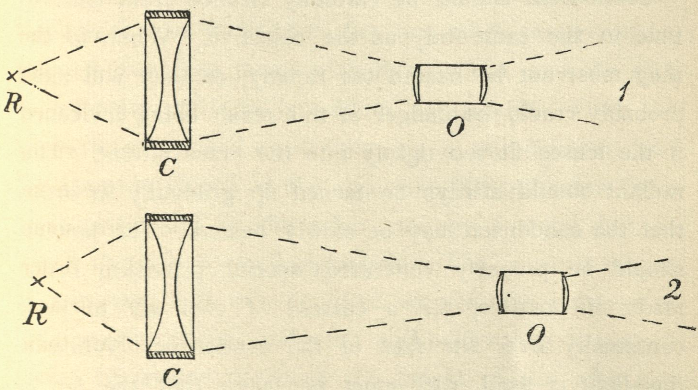

FIG. 5.

rays proceeding from the condenser fully illuminates the object without to any great extent passing outside it, and the whole of the cone, whilst still converging, should fall into the objective. Broadly stated, with a given condenser, the further the objective, the nearer the radiant and *vice versâ* (compare 1 and 2, Fig. 5). When projecting the image of apparatus, for example, it is almost always necessary to move the objective further away from the condenser, and then, in order to get the best

results the radiant must be moved nearer to the condenser. The further the lantern is away from the screen, the nearer will the objective be to the condenser when a slide is in focus, and consequently the further must the radiant be from the condenser, and *vice versâ*. After a little experience, the positions giving the best results will be easily and quickly found by trial.

Condensers should be carefully cleaned from time to time in the same way as the objective. When in use they must not be heated too rapidly, or they will most probably crack, the danger of this result being increased if the lenses fit too tightly into the brass mount. The radiant should always be turned up gradually in order that the condenser may be slowly heated. The lantern should be properly ventilated, special provision being made, if possible, for a current of cool air to pass continually over the face of the condenser. When a lime-light is used, care must be taken that the jet is not moved too close up to the condenser, and that the flame is not projected towards the condenser in consequence of pitting of the lime.

THE RADIANT will be either an oil lamp, or the lime-light with a blow-through or safety jet. The former is troublesome, cannot be used successfully in a room lighted by daylight, and cannot be used at all if it is necessary to tilt the lantern at any considerable angle; the latter is so simple to work now that oxygen can be obtained

compressed in bottles, and the results are so much more satisfactory, that its use is to be recommended wherever possible.

Oil Lamps for the optical lantern are now made with two or three wicks, each about two inches broad, placed parallel with one another, and arranged so that their edges are towards the condenser. Sometimes lamps are made with four wicks, but they are much more troublesome to use than lamps with three wicks, and the gain in intensity of light is seldom appreciable. Over the wicks is an arched cover carrying a tall chimney, and the lamp is closed at the end next the condenser by a glass plate, and at the other end by a metal door in which there is a small sight-hole. The cover is hinged at one end and can be lifted up for the purpose of lighting the wicks, and each wickholder has a toothed pinion by means of which the height of the wick can be regulated.

Considerable care is required in order to get the best possible results from an oil lamp. The wicks, which should not be too tightly woven, are cut into lengths of seven or eight inches, and carefully dried. They are then inserted into the wickholders and carefully trimmed with a sharp pair of scissors, the corners being slightly rounded off. After they have once been properly trimmed and have been used, they should never be touched with scissors; all that is necessary is to turn the wick up and

carefully wipe off the charred portion with a piece of soft paper. The lamp, after being filled with oil, should be allowed to stand for a short time before being lighted, in order that the wicks may become properly saturated with oil. It is important to remember that when the wicks are burning they should never be turned more than half down; if the flame is very low the wick chars to a considerable depth, and when the wick is turned up again the illuminating power of the flame is very poor.

Only the best paraffin oil or petroleum should be used; the cheaper and more volatile oils with a low flashing point are dangerous. The ordinary lamps hold about a pint of oil, and it is convenient to have a glass bottle holding about a pint, with a mark upon it showing the quantity of oil that fills the lamp. After use the oil is emptied from the lamp back into this bottle, which is then filled to the mark from the stock-can, and when the lamp has to be used again the whole contents of the bottle can be emptied into it with the knowledge that the lamp will then be properly filled.

One of the great drawbacks to the use of oil lamps is their tendency to produce a disagreeable smell, but this can be almost entirely prevented by the exercise of a little care. The lamp should be kept scrupulously clean, and care must be taken not to allow any fragments of charred wick to lodge in the wickholders. Before use the body of the lamp and the wickholders should be very carefully wiped with a dry cloth in order to

remove the thin film of oil which spreads over the surface and is one of the chief sources of the smell. This film of oil arises mainly from leakage through the joints of the pinions in the wickholders, and with a view to prevent this as far as possible, the reservoir should always be completely emptied of oil after use and before the lamp is put away. Dusting the body of the lamp with camphorated chalk, which is afterwards carefully wiped off, facilitates the removal of the oil.

THE LIME-LIGHT, oxy-hydrogen light, or oxy-calcium light is produced by blowing a jet of oxygen gas under small pressure through a flame of coal gas, hydrogen, or alcohol, and allowing the non-luminous flame thus produced to impinge on a piece of lime, which thereby becomes intensely heated and emits a very brilliant light. When very brilliant illumination is required the two gases are allowed to mix before they issue from the jet, but for all ordinary purposes the safety or blow-through jet is amply sufficient, and it is much easier to work. The blow-through jet usually has one of the forms shown in Fig. 6—the outer tube conveying the coal gas whilst the inner tube conveys the oxygen. The two gases meet only at the mouth of the jet, the arrangement of the tubes and taps, with the socket for supporting the jet, being shown in Fig. 7. It is essential that the tubes carrying the supply of the gases should be fitted to the proper taps, and if they are not already

marked, the oxygen tap should be distinguished from the other by nicking the edge in two or three places with a file.

The illuminating power of the jets is affected very considerably by the relative diameters and positions of the two tubes, and varies greatly in different jets. Some time ago the author made careful photometric comparison of a large number of jets from various sources, and three jets of pattern A (Fig. 6), made by Newton & Co.,

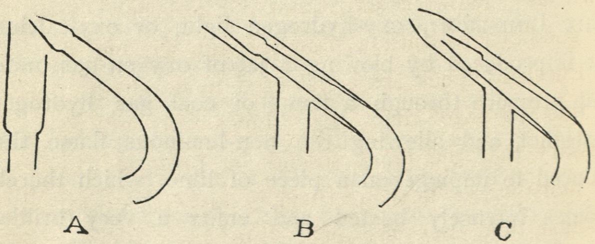

FIG. 6.

were found to be the best. The form B is the most common, and very good jets of this kind can be obtained; but many of them are very wasteful in their consumption of oxygen, and they should always, if possible, be tried before being purchased.

The lime cylinder is supported on a pin (Fig. 7), which should be provided with a cog-wheel arrangement for rotating the lime, this being worked by means of a rod extending outside the lantern. Sometimes the lime-pin and cog-wheels slide backwards and forwards, so

that the distance between the lime and the jet can be adjusted, the support, etc., being clamped by a screw. In other cases the lime-pin has no slide motion, the best position having been determined by the maker.

The limes are in the form of cylinders, which should be as accurately turned as possible, and have a central hole through which the lime-pin passes. This hole is usually filled with lime-dust, and must be cleaned out with a wire or a rat-tail file. The limes sold are known as "hard," "soft," and "Excelsior"; they all give good results with a blow-through jet, but the soft and Excelsior limes are considered to be slightly better for this purpose than hard limes. It is absolutely necessary that the limes should be protected from air and moisture. They are usually packed in tins with lime-dust, but they are best kept in a wide-mouthed glass bottle fitted with a good india-rubber cork; a brass tube with a screw cap provided with an india-rubber washer is also frequently employed. Before a lime is used the first time it should be thoroughly dried by being baked in an oven for half an hour or so. After use it should be put back into the bottle or brass tube as soon as it has cooled; if left in the lantern it will combine with the moisture in the air, and will crack and become useless.

When the jet is used, the lime is put in position, and the gas flame is lighted and turned up to a height of about an inch and a half, in order that the lime may

be gradually heated. After ten or fifteen minutes the gas is turned up, and the oxygen is slowly turned on until it roars. The oxygen is then turned off until the roaring stops, and the hydrogen is adjusted so that there is a slight excess of it, forming a *small* "wing" on either side of the lime. If a Beard regulator is used, the adjustment of the proportion of oxygen is done by means of the ordinary jet tap; but if a Beard or some equally efficient regulator is not used, *the jet tap must be left full on*, and the adjustment made by means of the tap on the bottle, a difficult thing to do without a large amount of practice.

If the position of the lime is adjustable, it is slowly moved towards the flame until a black spot appears in the centre of the luminous part, and it is then moved very slowly back until this black spot just disappears, and the lime support is clamped in this position, which will give the maximum illumination. This operation is, of course, done with the jet removed from the lantern. It is very important that the flame should strike the lime cylinder in the centre, so that the illuminated spot is exactly opposite the condenser, and not at the side, for the latter condition not only gives less effective illumination, but may tend to set the lantern on fire by producing a long wing of flame on one side of the lime. If the jet is so badly made that it shows this defect it should be at once rejected. The inside of the nipple of the oxygen jet should be carefully cleaned with a wire

from time to time, for any grit in the tube, or jagged edges to the aperture, greatly increase the tendency of the gas to roar.

The jets and tubes are provided with a socket (Fig. 7), and this slides on a vertical rod attached to one end of a flat piece of metal or tray which slides horizontally in grooves in the bottom of the lantern. The jet can thus be raised and lowered, or turned about in a horizontal plane, and is clamped with a screw.

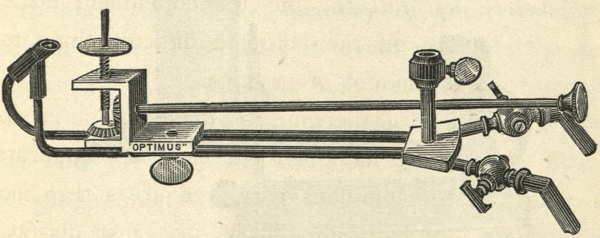

FIG. 7.

THE ALCOHOL JET (Fig. 8), is of great service in country places where coal-gas cannot be obtained; it gives more light than an oil lamp, but less than a blow-through jet with gas.* It consists of a spirit lamp with a circular wick, a jet of oxygen being blown across the flame, which is thus caused to impinge on a lime. A reservoir for the alcohol is outside the lantern, and communicates with the wick by a tube. The adjustment of the flame is made in very much the same way as in

* These jets can be obtained from almost all dealers.

the case of a gas jet, the size of the alcohol flame being regulated by the height of the wick. Soft limes give the greatest amount of light with this flame.

Compressed Oxygen is now supplied in steel cylinders which can easily be sent by rail to any part of the country; the apparatus required for use in connection with them is a Beard's small regulator, and a key for

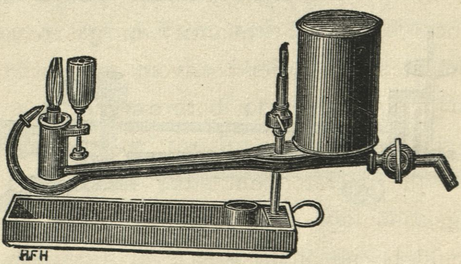

Fig. 8.

opening the cylinder tap. Since the gas is under very high pressure, proper care must be exercised, and the instructions of the manufacturers must be carefully followed. Care must be taken that no grit gets into the threads of the screws, or into the cones; and when a regulator, valve, etc., is to be screwed on, it must be fitted carefully into the socket without any inclination to one side or another. The screws should be turned until they are quite gas tight, but should not be screwed up too far, for they will then be very difficult to unscrew, and the thread of the screw may even be

stripped off. Taps should always be turned on slowly and turned off slowly, in order to avoid sudden variations in pressure. A simple and efficient way of testing whether a joint is gas tight or not, is to moisten it with a little water, or better, saliva, and observe whether any bubbles of gas make their escape.

In order to ascertain how much gas is left in a bottle, the pressure is measured from time to time with a pressure gauge, and if the capacity of the bottle is known once for all, the quantity of gas remaining is easily calculated. In order to avoid accidents the same gauge should not be used for both oxygen and hydrogen, and the glass face of the instrument should be turned away from the operator until the pressure is full on. The gauge should not contain any oil or grease, and there should be no oil or grease on the screw fittings. The tap should be turned on very slowly, and indeed it is best to turn the cylinder tap until the oxygen escapes slightly before screwing the pressure gauge into its place.

Since a cubic foot of oxygen weighs 1·43 ounce, or 1 ounce of oxygen occupies 0·7 cubic foot, the quantity of gas in a cylinder can be ascertained by carefully weighing it, if the weight of the empty cylinder is known. By weighing it before and after an exhibition, the difference in weight will give the quantity of oxygen used, even though the weight of the empty cylinder is not known.

Compressed coal-gas or hydrogen can also be obtained in bottles, and is a great convenience when an ordinary gas supply is not available. It is used with a Beard regulator in the same way as the oxygen; it is very important not to put on the hydrogen bottle a regulator that has been used for oxygen, and *vice versâ*.

The cylinders may be laid on a table when in use, a long wedge-shaped piece of wood being placed on either side of them to prevent them from rolling off, or they may be supported vertically in an iron tripod stand. The best plan, however, is to have a strong wooden box which holds the cylinder in a vertical position and is sufficiently high to contain the regulator as well as the cylinder. The top lid is hinged, and one of the sides is also hinged just below the shoulder of the cylinder, in order to give access to the regulator and the bottle tap. The lids should be fitted with a lock, or padlock, so that any tampering with the cylinder when not in use may be prevented.

THE LANTERN itself should be as small in the body as possible, with a view to secure portability, and to avoid obstruction of the view of people seated behind it. It should not, however, be so small that there is a danger of the woodwork at the back taking fire. Lanterns with Russian iron bodies work well, but become very hot, and it is preferable to have a wooden

body with a metal lining, there being a clear space between the wood and the metal in order to secure proper ventilation. When slides have to be shown, a stage or holder for the slide carrier is necessary, and it must bring the slide as close as possible to the condenser. When experiments in tanks have to be performed, the holder or stage must be open at the top (Fig. 9); when the image of apparatus has to be

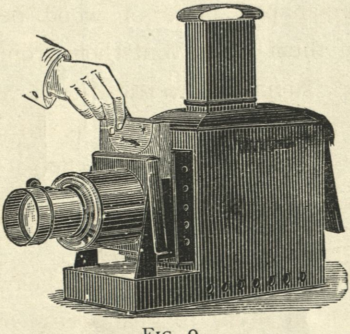

FIG. 9.

projected on the screen, the objective must be capable of being moved to some distance from the condenser, as in what is known as the "Sciopticon" form of lantern.* The "Cantilever" lantern of Hume has certain special features, which are clearly shown in the illustration (Fig. 10); the front bellows can be removed

* N.B.—It must be distinctly understood that a cheap and simple lantern of the class shown in Fig. 9, is all that is necessary for ordinary class-work. The more elaborate lanterns are described for the benefit of science teachers.

when apparatus is to be shown, and the horizontal rods support a small stand carrying the apparatus. It cannot however, without slight alteration, be used to the best advantage for showing slides, unless fitted with a 4-inch condenser. The Chadwick lantern (Fig. 11), though some-

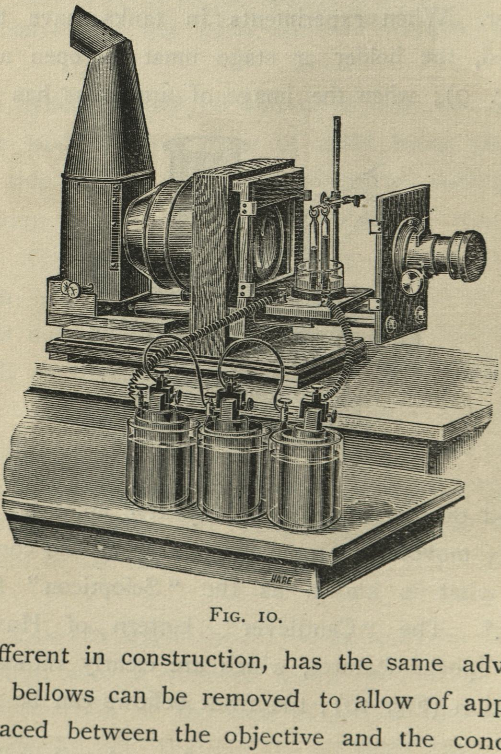

FIG. 10.

what different in construction, has the same advantage that the bellows can be removed to allow of apparatus being placed between the objective and the condenser, whilst it is equally suitable for showing slides. The "Ideal" of Archer & Sons (Fig. 12), is of a similar type.

Sometimes apparatus or experiments must be shown with the apparatus in a horizontal and not a vertical position. The objective is then removed, and the cone of light from the condenser is allowed to fall on a mirror placed in front of it at an angle of 45°. The

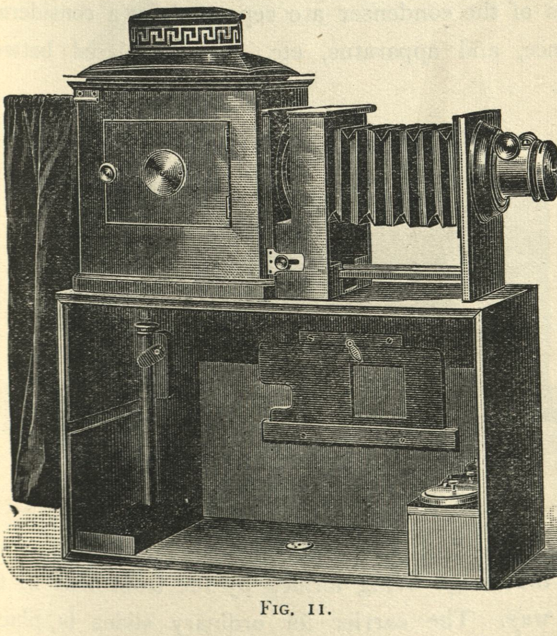

FIG. 11.

beam of light is thus sent vertically upwards, passes through the apparatus (which is supported in a convenient manner) and through an objective; it is then received on another mirror at an angle of 45°, and is thus projected on the screen. Messrs. Newton & Co. have devised a double lantern, both parts of which can

be used in the ordinary position, or one of them can be turned up vertically, as shown in (Fig. 13), for the projection of horizontal objects. A still newer lantern by Stroud & Rendall (Fig. 14), has been designed to satisfy all ordinary lecture requirements. The two lenses of the condenser are separated by a considerable distance, and apparatus, etc., can be placed between

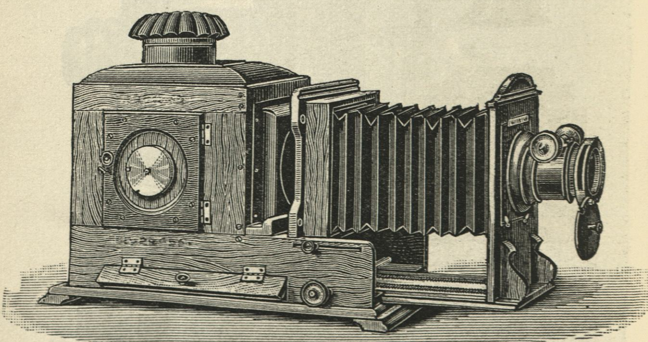

FIG. 12.

them, the image being formed by the front lens in the usual way. The carrier for ordinary slides is placed in front of the second lens of the condenser. Objects that must be kept in a horizontal position are placed on a third single condensing lens fixed horizontally, and a mirror which is let down between the two vertical condensing lenses projects the beam of light upwards. This beam passes through a lens attached to a vertical

support, and is projected on to the screen by means of a mirror. Diagrammatic slides can be placed on the horizontal condenser, and a needle can be used for pointing out the various parts of the diagram, the

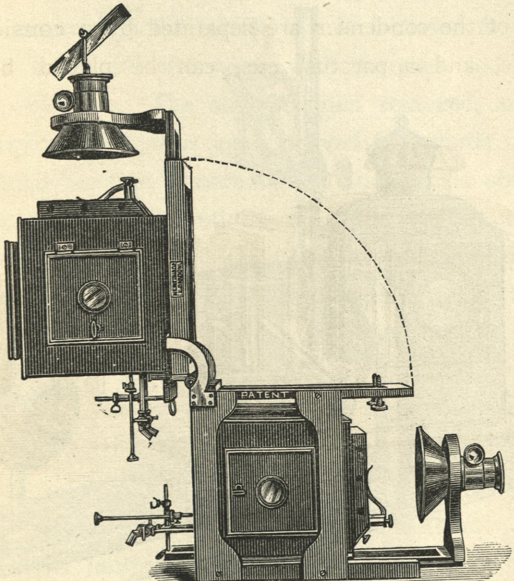

FIG. 13.

image of the needle of course appearing on the screen. The jet also has some novel improvements, which make centering easier, whilst at the same time there is less liability of the jet being accidentally displaced after it has once been fixed. There is also a special by-pass tap, which turns down the oxygen and hydrogen together

after the proper proportions have been adjusted by means of the ordinary jet taps.

The adjustment of the lantern and its parts should be made with some care. The proper distance having been determined (see table p. 25), the lantern is placed with

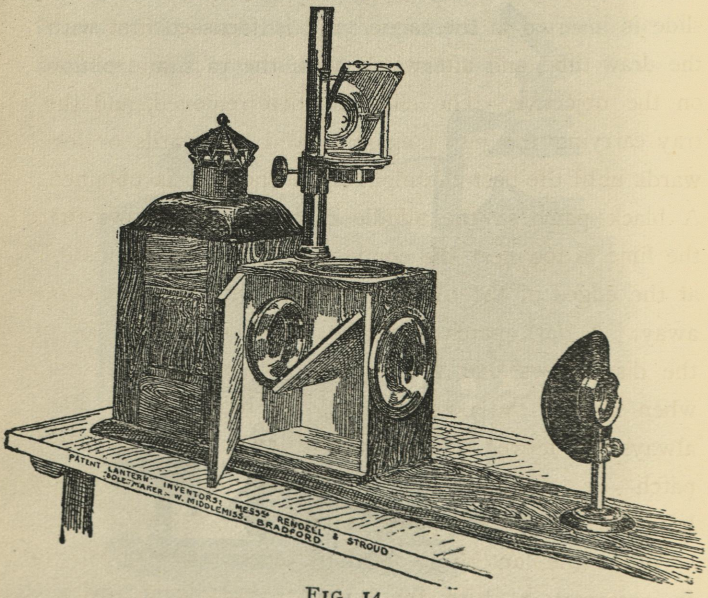

FIG. 14.

its axis exactly at right angles to the screen, and with the objective pointing to the centre of the screen. The jet with a lime is put into position, and the gas is lighted and allowed to remain with a flame at the height of 1½ to 2 inches for a short time in order to warm the condenser of the lantern. The gas is then turned up and the oxygen turned on as already described

and the lime is centred by moving the jet up or down, and to right or left until the circle of light is in the centre of the screen. The tray carrying the jet is now moved nearer to or further from the condenser until the disc on the screen is fully and evenly illuminated. A slide is inserted in the carrier and is focussed first with the draw tube, and afterwards with the rack and pinion on the objective. The slide is then removed, and the tray carrying the jet is again moved backwards or forwards until the best illumination of the disc is obtained. A black patch in the middle of the screen shows that the lime is too near the condenser; want of illumination at the edges of the disc shows that the lime is too far away. A dark patch near the top, bottom, or side of the disc shows that the lime is not properly centred; when making the readjustment, the lime and jet must always be moved in a direction away from the dark patch—*i.e.*, to the right, if the dark patch is on the left; up, if the dark patch is near the bottom.

When the lantern is used for any length of time, it is necessary to turn the lime occasionally in order to prevent the formation of a hole by the continued action of the flame on one spot.

A CARRIER for the slides is necessary, and many different forms can be obtained. It must be fixed just in front of the condenser, and must bring the slide as close to the face of the condenser as possible. Nothing

is better than the double sliding carrier, consisting of a part that remains in the lantern, and a part that moves backwards and forwards, carrying the slides with it. The movable part consists of two frames, one of which holds a slide in its proper position in the lantern, whilst the other projects at the side, and can be emptied and refilled. The slider is then pushed across, and the new picture goes into position whilst the old one projects from the other side, and can be removed.

Slides are put into the carrier upside down, with their faces towards the condenser. It is advisable to mark them in what is now adopted as the regulation manner. Place the slide in front of you so that the picture is in its correct position as regards top and bottom, right and left. Now put a small circular or square patch of paper on the face of the slide at each of the top corners, or a strip of white paper across the top. The slide will be in its correct position in the camera when the white patches or line are at the bottom and next the condenser. For further details, and for instruction as to the methods of performing various experiments, the following books may be consulted: "The Book of the Lantern," by T. C. Hepworth; "The Optical Lantern," by A. Pringle; "Optical Projection," by Lewis Wright.

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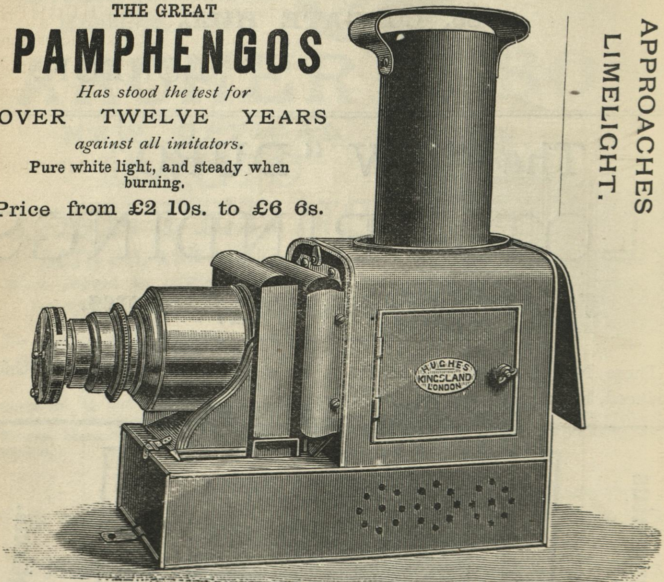

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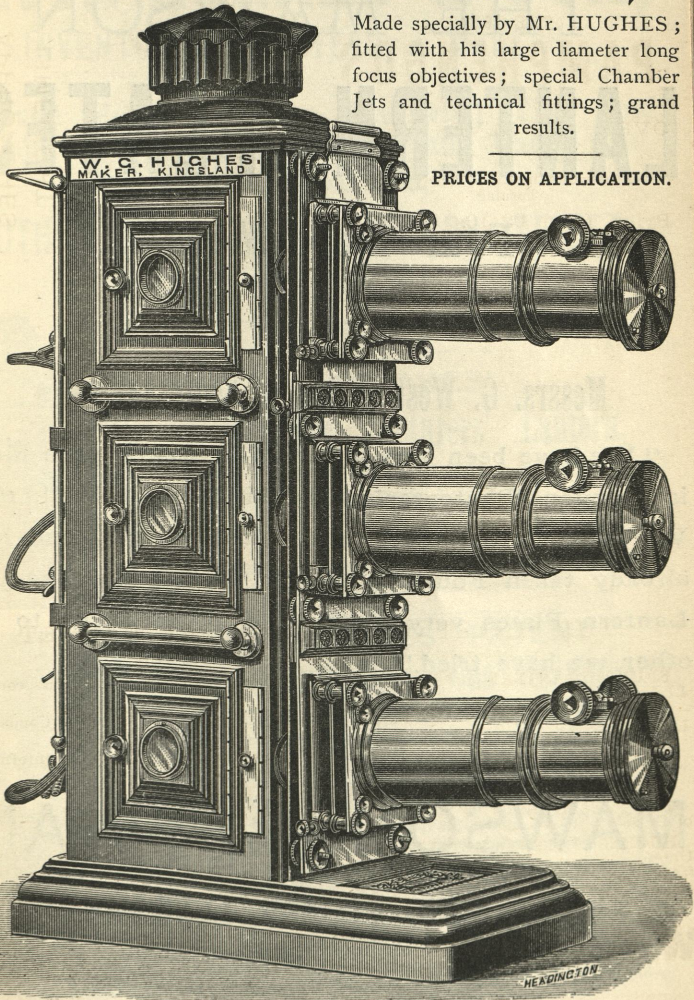

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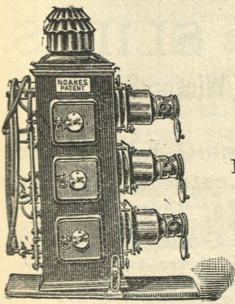

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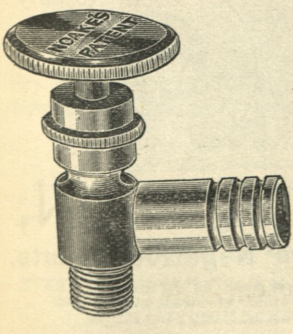

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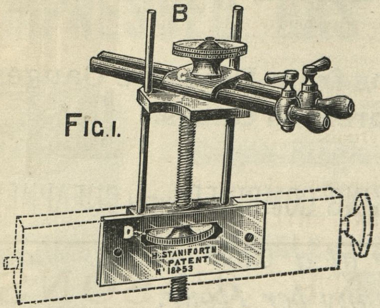

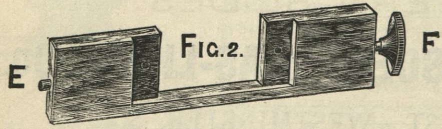

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To adapt the Jet Holder to single lanterns see fig. 2, which is a piece of wood 1½ in. wide. At one end is a peg **E**, at the other a set-screw **F**. To fix it into the Lantern make a hole on one side for the peg, and one on the other side for the set-screw.

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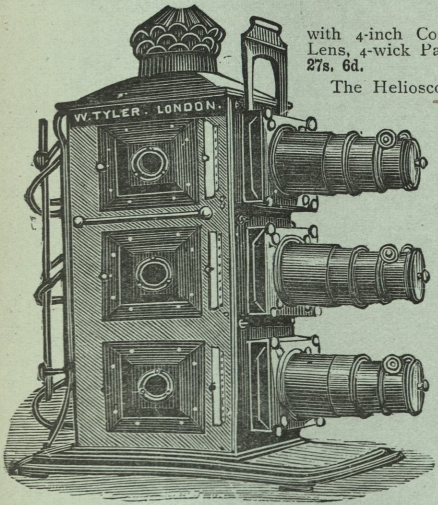

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